CLIL and Science education.
A review for a Language focus in Science teaching

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Abstract

This article aims to review literature on CLIL (Content and Language Integrated Learning) theory and practice, particularly during Science classes using English as a foreign language. In Europe, the CLIL approach – directed at the acquisition of both the additional "Language" and subject "Content" – has arisen to promote foreign language learning, but it could also be beneficial for the specific subject education. To support learners in understanding scientific information and taking responsible socio-scientific decisions, Science communication (its verbal language and other representation modes) should be emphasised over facts and formulas and addressed as a key competence. Studying CLIL programmes, which nurture language learning/use within Science education, becomes relevant. As a state of the art this work shows aspects of CLIL emergence and evolution and research gaps, such as CLIL as an educational methodology to enhance Science teaching. This study contributes to research on CLIL Science and language-focused Science education towards scientific literacy.

L'articolo offre una revisione della letteratura sulla teoria del CLIL (*Content and Language Integrated Learning*) e sulla sua pratica, relativa alla Didattica delle Scienze con l'Inglese come lingua straniera. In Europa, l'approccio CLIL – rivolto all'acquisizione sia di una seconda Lingua (*Language*) sia del Contenuto (*Content*) di una disciplina – è nato per promuovere l'apprendimento delle lingue straniere, ma può essere vantaggioso anche per la didattica di altre discipline. Per sostenere gli alunni nella comprensione dell'informazione scientifica e nel prendere decisioni socio-scientifiche responsabili, la comunicazione scientifica (linguaggio verbale ed altre modalità di rappresentazione) deve prevalere su fatti e formule ed essere affrontata come una competenza chiave. Lo studio di programmi CLIL che coltivino l'apprendimento/uso della lingua nell'ambito della Didattica delle Scienze diviene rilevante. Questo stato dell'arte mostra aspetti dell'origine ed evoluzione del CLIL e possibilità di ricerca, come l'adozione della metodologia CLIL per migliorare l'insegnamento delle Scienze. Ciò contribuisce alla ricerca sul CLIL di Scienze e a un'educazione scientifica incentrata su lingua e linguaggi, per sviluppare l'alfabetizzazione scientifica.

Valentina Piacentini – *CLIL and Science education. A review for a Language focus in Science teaching*
DOI: https://doi.org/10.6092/issn.1970-2221/12646

Keywords: CLIL (Content and Language Integrated Learning); Science education; EFL (English as a Foreign Language); literacy; state of the art reviews

Parole chiave: CLIL (Content and Language Integrated Learning); educazione scientifica; ILS (Inglese come Lingua Straniera); alfabetizzazione; rassegna in forma di stato dell'arte

DOI: https://doi.org/10.6092/issn.1970-2221/12646

1. Introduction

Science education has a pivotal role in the information society and for lifelong learning. According to Martins (2014) and Salehjee and Watts (2020), Science is a part of contemporary culture and represents a way of thinking and understanding (2014). Unfortunately, disappointing results of worldwide monitoring studies such as PISA, among others, have shown a poor "transferability" of school Science knowledge into "comprehension" of everyday natural phenomena, underlining the necessity to increase the level of scientific literacy and to improve the quality of Science instruction (Duit, 2007; Roberts & Bybee, 2014). Two decades ago, Hurd (1998) already noted that «science curricula need to be reinvented to harmonise with changes in the practice of science/technology, an information age, and the quality of life» (p. 411). Contextualising the learning of Science, as well as broadening the range of opportunities to learn it, is crucial if Science is to be significant for learners' lives and their identities (Aikenhead, 2003; Salehjee & Watts, 2020) and is to support them in distinguishing facts from myths, theories from dogmas, knowledge from opinion, evidence from propaganda, using some of Hurd's words (1998, p. 413).

Ultimately, a scientifically literate person is supposed to understand and integrate scientific information, engage with and take responsible decisions about socio-scientific issues (Holbrook & Rannikmae, 2009; Hurd, 1998; Martins, 2014; Roberts & Bybee, 2014). Howell and Brossard (2021) consider that those literate citizens should be able to communicate collaboratively, and "navigate" complex and dynamic societal issues (of which climate change and Covid-19 are pertinent examples) as well as (mis)information to form opinions on that information. If we interpret «the nature of science [as] for all and aligned with functionality in society», as Holbrook and Rannimkae (2009) delineate, «a familiarity with language, or communication tools in general, can play a role [...] to know how to extract and handle information» (p. 282). From the perspective of a simultaneous process of "learning language" and "learning through language" (Halliday, 1993), language is a "central mediator" of Science learning and Science classes are, as Espinet, Izquierdo, Bonil and Ramos-de Robles (2012) maintain, interactional spaces where scientific explanations of natural phenomena are constructed using the resource of language.

Communicating with the use of her/his mother tongue (L1), each learner is a sense maker whose agency is transformed and expanded in the presence of a diversity of languages or representation modalities (cf. "the pedagogy of multiliteracies" by Cope & Kalantzis, 2009). Meaning making activity, thus, occurs in Science classes through a multimodal learning environment (Bezemer & Kress, 2020). Studies on Science teaching have already begun to integrate language fields (e.g.: Buxton & Lee, 2014; Cabello, Salinas Barrios, & Geelan, 2019), nevertheless, reflection on giving a Language focus to formal Science education should be encouraged, also in agreement with Lemke (2003) and Wellington and Osborne (2001), who claim that for many students the greatest difficulty (and the most important achievement) is to learn the language(s) of Science[i].

On a different level, being competent in foreign languages (FL), albeit to varying degrees, is also fundamental (European Commission, 2003), not least for people participating in scientific and general discussion. Global demand for learning English and through English has been growing (Lin, 2016; Marsh, 2006). Rather than "one foreign language", it is nowadays viewed as a "lingua franca" and a social practice (Jenkins, 2015). Actually, as Dearden (2014) and Marsh (2006) remark, English is the language of the scientific community, technol-

DOI: https://doi.org/10.6092/issn.1970-2221/12646

ogy and multimedia, useful for professional mobility and cultural encounters, and skills in this language have become a paramount competence for higher education.

For the purpose of this work, we will not discuss the role of English in international Science research. Instead, discussing the provision of opportunities for an authentic learning of this language and exploring facets of how English might sustain the learning of Science and vice versa, for example when "integrated" as a non-native language during Science classes within specific programmes, seems significant. Particularly prolific in the European framework, the "Content and Language Integrated Learning" (CLIL, henceforth) educational approach is practiced in these programmes under many guises, with the aim being students' learning in terms of both the additional Language[ii] and specific subject Content (see later sections). Within CLIL, teachers can develop meaningful learning environments at school, where English (Language) is "naturalistically" used and learnt during Science (Content) classes; these, in turn, tend to be implemented through the use of supporting strategies and contextualised practices to involve learners (see §3.). For scholars, CLIL could serve as a context to gauge the importance of (Science) teachers' language awareness, a quality advocated by researchers both inside and outside of the CLIL field: Bezemer & Kress, 2020; Coyle, Hood, & Marsh, 2010; Lemke, 2003; Llinares, Morton, & Whittaker, 2012; Wellington & Osborne, 2001; Wolff, 2012.

It may reinforce in the Science curriculum the literacy activities of talking, reading, writing and doing alluded to by Pearson, Moje and Greenleaf (2010). In fact, Wellington and Osborne (2001) assert that a Science teacher is also a teacher of language(s), the teaching of those skills being not only a responsibility of language teachers (Sanmartí, 2007). Besides being beneficial for a higher proficiency in the target language (see §3.2.), CLIL Science practice may also be beneficial for Science education and conceptions about Science, as specific studies suggest (e.g.: Blanchard, Masserot, & Holbrook, 2014; Valdés-Sánchez & Espinet, 2020). Therefore, it is necessary and germane to establish a more comprehensive understanding of CLIL's underpinnings, as well as to unearth its potential for improving Science education and literacy by reviewing associated literature. This is the goal of this article.

2. Literature review process

To establish a wider context on CLIL theory and practice, we read seminal and review documents as well as the most cited works in this field. We also performed multiple structured searches with two foci (Tab. 1). The first focus allowed for understanding the specificity of the relatively recent and contextualised research on CLIL Science practice using English as FL or L2, whereas the second one accounted for the broad presence (in space and time) of "language implications" in Science education research. In the first case empirical articles (observing practices through existing models; measuring outcomes through tests; using double-checked discourse/conversation analysis) were found and analysed. Due to the already conceptualised nature of the second focus, the search also resulted in theoretical chapters and review papers. Articles selected in both cases were published in journals using double blind peer-review and (all but three) indexed in Scopus or Web of Science.

DOI: https://doi.org/10.6092/issn.1970-2221/12646

Database	Focus	Space	Time	Publication type
Scopus Web of Science EBSCO	CLIL Science practice with English	European context	Last 15 years	Empirical articles of both a qualitative and quantitative nature
Google Scholar B-on	Science education with "language" implications	International context	Longer interval	Theoretical chapters, reviews and empirical articles

Table 1: Searches to obtain and analyse a body of literature concerning, specifically, two foci

One output of the second focus was already given in Piacentini, Simões and Vieira (2017), through the description of theoretical frameworks or referential concepts related to Science educational approaches that are aware of languages or directed to literacy (classroom discourse, meaning making and modalities used to represent the subject; Science genres and activities; CLIL, non-native English Science learners and language demands).

Moreover, to understand the areas in which works on CLIL Science are published, we carried out a search at the beginning of 2020, through the query of Tab. 2, finding 75 results (33 + 42 in the table). After excluding the 33 publications not associated with implemented CLIL Science classes, we found that almost 60% of those included were issued by journals connected with language teaching, bilingual education or applied linguistics.

Database	Time span	Descriptors	Excluded (33)	Included (42)
Scopus[iii]	2005-2020	CLIL, Science, school (in the title, abstract and keywords)	**26**, Science not being the or one actual specific subject to learn in compulsory school; **7**, about graduate teacher education or preparation	**24**, language learning or language promotion journals; **8**, general educational areas; **7**, Science Education; **3**, other areas.

Table 2: Query, excluded and included publications

Our work can be framed as a "state-of-the-art review" (Grant & Booth, 2009), because it brings a new perspective on CLIL as an approach for Science education and identifies opportunities for further research. Applying the review categories of these authors, we can say that the text below and Fig. 1 (see §3.6.) «go beyond mere description of identified articles and include a degree of analysis and conceptual innovation» (p. 93), hence this is also a "critical review".

3. State of the Art review

The following review starts from CLIL theory and practice (3.1., 3.2. and 3.3.) and leads to research on "language implications" in Science education (3.4. and 3.5.). Finally, it illustrates this flow (3.6.).

DOI: https://doi.org/10.6092/issn.1970-2221/12646

3.1. CLIL and a "new old" approach for the learning of foreign languages

In Europe CLIL has emerged as one solution through which European citizens can become competent in European languages besides their own (European Commission, 2003). Coyle (2013) acknowledges it as a "change agent", in converting «monolingual learning contexts into bilingual experiences» and moving «towards a more equitable distribution of linguistic and social capital» (pp. 244-245), though Dalton-Puffer (2011) counsels that CLIL should not be perceived as a "panacea".

While the theoretical underpinnings and methodological concerns of CLIL arose almost 50 years ago from immersion programmes of the bilingual education in the French speaking Canada, the term[iv] was coined by Maljers and Marsh only in 1994. In 2002 this last scholar, an early reference for CLIL, characterised it as «any dual-focused educational context in which an additional language [...] is used as a medium in the teaching and learning of non-language content»; in later works, CLIL would be viewed as an "umbrella" term for educational practices and settings having in common that a non-L1 is used in non-language classes (Dalton-Puffer, 2007).

The CLIL approach is, according to Lin (2016), a type of content-based instruction (CBI[v]). In a more typically European research context, it is considered to share "essential properties" with CBI, "accidental differences" being due to historical and contextual factors rather than to different programme design principles (Cenoz, 2015). The main difference between CBLT (content-based language teaching) and CLIL described by Dale and Tanner (2012) is that the former consists of teaching content in language lessons, whereas the latter consists of teaching a discipline at the same time as teaching the language.

Some early studies (Jäppinen, 2005; Wolff, 2012) and some researching the Spanish reality (Fernández-Sanjurjo, Fernández-Costales, & Arias Blanco, 2019; Hughes & Madrid, 2020), for example, associate CLIL with bilingual education and immersive forms, which expose students to a language and promote its learning through teaching one or several non-linguistic subjects in the second language (L2, not FL), partly or completely (Gajo, 2007). The association with bilingual practices seems reasonable for countries with other official languages (Catalonia in Spain, the Valle d'Aosta and Trentino Alto-Adige regions in Italy, Flanders in Belgium are some examples) or with minorities (for instance, Estonia and Sweden), where bilingualism is a reality and the CLIL language is the other state language or a minority one, respectively.

Nevertheless, as reminded by Lasagabaster and Sierra (2010), differences from Canadian immersion have appeared over time in CLIL programmes, such as the "non-nativeness" of teachers and students, lower time of exposure and readapted (from those for native-language learners) or scaffolding (cognitive and interactive support for language difficulties) teaching materials. In fact, in line with these authors, CLIL practice does not imply that teachers are native speakers in the target language and does not aim at a bilingual-like learner proficiency. Also, within immersion programmes, language learning during subject lessons may be incidental (Gajo, 2007) or not explicit (Dale & Tanner, 2012).

3.2. CLIL language education: approach, skills, target languages and changing perspective

CLIL is assumed as an alternative to Communicative Language Teaching (Coyle et al., 2010) or a way of extending it (Dalton-Puffer, 2007; Lasagabaster & Sierra, 2010). Arising from a need to promote the learning of

DOI: https://doi.org/10.6092/issn.1970-2221/12646

foreign languages, the principle of CLIL, based on Krashen's 1982 theory on Second Language Acquisition, is that students are exposed at school to the CLIL target language and, reflecting the importance of the socially situated nature of language development, learn how to speak while they authentically use it in and for the subject thematic learning (Coyle et al., 2010; Llinares et al., 2012; Marsh, 2012). CLIL has, thus, been described as an environment favorable for and enriching FL learning (e.g.: Coyle et al, 2010; Dalton-Puffer, 2007; European Commission, 2017; Mariotti 2006) and referred to as a "meaning-focused" and "content-enriched" method to improve the FL education (Xanthou, 2011). According to Dale and Tanner (2012), diverse benefits exist for CLIL learners, FL skills (receptive/productive lexicon, morphosyntactic resources, spontaneous oral production; see Dalton-Puffer, 2011) having indeed been strengthened through CLIL. Further value is seen in increased students' attitudes and motivation towards language learning, among other cognitive gains (see Pavón Vásquez & Ellison, 2013).

CLIL programmes and initiatives have been spreading in the last decade, across school levels, at the tertiary level and in adult learning, also in countries (Cyprus, Denmark, Portugal) not identified before (European Commission, 2006, 2017). Actions like top-down programmes or bottom-up initiatives, pilot projects and low/medium/high immersion are listed under the name of CLIL in European and other reports. Coyle et al. (2010) and Pavón Vázquez and Ellison (2013) indicate that CLIL is flexible and there is no formula for organising a CLIL programme nor a template for planning CLIL lessons; it is the context and the discipline that determines them. However, in the CLIL-4Cs Framework (Coyle et al., 2010) it is highlighted that the interrelationship between the 4Cs – Content as new knowledge and skills, with related Cultural and societal issues, through activities which offer Cognitive challenge, while students Communicate – may lead to effective CLIL (pp. 53–56).

As Dale and Tanner (2012) report, CLIL students have to "work harder" cognitively because of the FL, but the process which they deal with may enhance understanding of subject concepts (as reinforced in the next section), thinking skills and likely creativity. Marsh (2012) explains that it is «the management of two or more active language systems, and the experience of that [...] over time that could foster an overall higher mental flexibility» (p. 329). This aspect notwithstanding, an explicit foreign language instructional support should be provided to avoid the overload of working memory, especially for novice learners (Roussel, Joulia, Tricot, & Sweller, 2017).

In Coyle's et al. work (2010), it is illustrated that Communication takes place with the languages "Of" (specific subject language[vi]), "For" (general academic language[vii]) and "Through" (language emerging from the process[viii]) learning, which constitute the «[target] language tryptich» (pp. 60-63). The use of the additional language but also the mother tongue as well as of other languages in learners' repertoires is, according to Moore, Evnitskaya and Ramos-de Robles (2018), «a resource, rather than a hindrance, for constructing knowledge» (p. 348). For this reason, while teachers and students are using the FL/L2 as the medium of learning, they should be allowed to resort also to their L1 through "translanguaging" practices (Moore, Evnitskaya and Ramos-de Robles, 2018; Williams & Tang, 2020).

In CLIL programmes, the choice of the target subject depends on the level of instruction and on its cognitive demands in terms of language itself: for instance, Philosophy or Literature relies mainly on verbal communication, whereas Biology or Geography are represented also visually (Barbero, 2006). Any language can be

DOI: https://doi.org/10.6092/issn.1970-2221/12646

selected, but, from the point of view of Cenoz (2015), Lasagabaster and Sierra (2010) and Lin (2016), the adoption of English has grown in schools and "occupied" CLIL provision, leading Dalton-Puffer (2011) to rename CLIL as "CEIL", where "E" stands for English. However, as noted by Piacentini and Simões (2020), the English learnt in a CLIL environment functions as a bridge to learn other FL and of other cultures (as well as their own) and, "without leaving home" (to quote Beleen & Jones, 2015), might add a universal outlook in the study of disciplines like Science. In fact, CLIL is described by Beacco et al. (2010) as one possible strategy to promote plurilingual and intercultural education, since students happen to «communicate with people from other cultures [and form] international perspectives on the subjects they are learning» (Dale & Tanner, 2012, p. 13). Marsh (2006) also suggests that the «absorption of a utilitarian command of English through the new technologies» (p. 35) could raise motivation to learning through CLIL, when the target language is English.

3.3. The dual focus in CLIL-based education and benefit for specific curricular areas

Unlike traditional FL classes, where the form and structure of the target language are the main object of study, within CLIL settings the mastery of Content (non-linguistic, specific subject which is represented and constructed through language) and the acquisition of the additional Language form a "dual focus" of both teaching and learning, in agreement with references of CLIL as an educational concept, such as Coyle et al. (2010), Marsh, Mehisto, Wolff and Frigols Martín (2011), Pavón Vázquez and Ellison (2013). The degree of collaboration between Content and Language teachers is somewhat implied in CLIL, where they learn from each other and from an enhanced reflection on their pedagogical practice (Dale & Tanner, 2012; Pavón Vázquez & Ellison, 2013; Valdés-Sánchez & Espinet, 2020).

The dual focus entails "hard work" for teachers and students (Bruton, 2013), the latter facing the cognitive demands of a given activity (Dale & Tanner, 2012). On the other hand, Grandinetti, Langellotti and Ting (2013), Mehisto (2012) and Wolff (2012) maintain that quality CLIL implementation is centred on learners because CLIL may foster their autonomy and cooperative learning (through peer/group and project works), self and peer formative assessment, and it is based on intention and process visibility, although this positive change in classroom pedagogies is not guaranteed (Dalton-Puffer, 2011). Moreover, CLIL classes can cater to a broad spectrum of multiple intelligences, in Dale and Tanner's opinion (2012), but require the development of a "language-supportive pedagogy" (Clegg, 2007) also through diversified scaffolding strategies[ix].

Notwithstanding the «[teacher's] effort to master the CLIL methodology, over time the linguistic pressure is released» (Oattes, Oostdam, de Graaff, & Wilschut, 2018, p. 167) and CLIL could serve as a beneficial learning context for non-FL teachers. Professional and personal challenges encountered teaching with/in the L2 increase teacher awareness of learner linguistic needs (Blanchard et al., 2014; Marsh, 2012) and «may favour a more profound treatment of content» (Escobar Urmeneta & Evnitskaya, 2014, p. 178). From Gajo's perspective (2007), the subject knowledge/learning might even be "un-densified" through the use of the L2 and clarifying its "discourse opacity"[x], offering an opportunity for teachers to deal with content language facets, otherwise not noticed (Moore, Evnitskaya and Ramos-de Robles, 2018).

DOI: https://doi.org/10.6092/issn.1970-2221/12646

Hence, the L2 should not cause major difficulties in implementing CLIL classes; Barbero (2006) clarifies, instead, that the lack of appropriate methodology used in class does. Also, «changing the medium of instruction [...] does not automatically qualify as an example [of CLIL]» (Marsh, 2006, p. 33). Students not having sufficient time to apply what they have learnt is indicated as the main constraint (Beacco et al., 2010; Coyle et al., 2010; Milton & Meara, 1998). Curriculum and policy constraints, as well as restrictive existing material, are other obstacles identified by Coyle et al. (2010). The limited access to CLIL programmes for some students pointed out by Bruton (2013) is another problem to take into consideration.

In spite of these aspects and in entailing "language-sensitive content teaching" strategies that prepare CLIL and non-CLIL teachers to work in CLIL-like contexts in European schools, CLIL is regarded as a "change agent" also by Wolff (2012), who remarks that, due to the increasing migratory phenomena, "conversational" and "academic" competence levels in the schooling language among learners are heterogeneous. The adoption of the language awareness in CLIL posited by Piacentini, Simões and Vieira (2019) through "CMIL" (Content and Mother tongue Integrated Learning, that is, the CLIL approach also when the teacher's and students' L1 is used), to improve the communication and understanding of specific disciplines, might thus be meaningful. This study echoes the policy envisaged in "Language Across the Curriculum" which asserts that «language education [...] take[s] place also *in each and every other subject* [than language]» (Vollmer, 2007, p. 178).

3.4. Science education and languages promoted through CLIL towards scientific literacy

Language does have a role in knowledge construction in the Science classroom and has been changing, according to Espinet et al. (2012), from transmitting information to making sense of experience to participation in communities of practice, language being central in Science teaching and learning processes. In acknowledgement of the Vygotskian theory of learning in social interaction, language use with others is the essential mediating tool in cognitive development (see Llinares et al., 2012). Within this semiotic account, concepts are «drawn out, written out, acted out, talked about [...] Science is communicated multimodally» because concepts become «materially evident as signs» and teachers and learners are «meaning makers» through different modes (Bezemer & Kress, 2020, pp. 73-74). Consequently, Pearson et al. (2010), Polias (2016) and Sanmartí (2007) recommend that Science must also be taught/learnt to be "talked", read and written.

If this effort is implicit (or absent) in regular Science education in which the communication occurs via L1 (Grandinetti et al., 2013; Lemke, 2003; Moore et al., 2018; Scott, Mortimer, & Aguiar, 2006), studies focused specifically on CLIL Science teaching and learning, such as Piacentini, Simões and Vieira (2018), Blanchard et al. (2014) and Grandinetti et al. (2013), reveal that, when the Science teacher ends up working in CLIL settings, her/his FL "limitations" might lead her/him to make content more accessible to students and language more centred on them, as well as to a relationship less based on the teacher lecturing and less hierarchical with them. As Canet Pladevall and Evnitskaya (2011) remind, CLIL subject teachers are engaged in «a constant process of rethinking the way one teaches» (p. 176), questioning their own strategies and methodology, which can facilitate Science learning and improve Science education and students' performance (Grandinetti et al., 2013; Jäppinen, 2005).

DOI: https://doi.org/10.6092/issn.1970-2221/12646

As expounded on scientific literacy in the introduction and aligning with scholars devoted to research on (and who encourage) a language-focused Science education, a major obstacle in learning Science is to learn its diverse language, which is "like learning a new language" (Wellington & Osborne, 2001, p. 5). After all, «we teach in the languages of science, but we do not very often teach students about those languages» (Lemke, 2003, p. 11). The integration of these languages – verbal, visual, mathematical, kinaesthetic, among others – with each other and with other modes – for instance, the audio, emotional, spatial ones – within Science learning aids, engages and empowers learners, as suggested by Cope and Kalantzis (2009) and Williams and Tang (2020).

Using Cope and Kalantzis's words (2009), the old literacy teaching, which «confined itself to the forms of written language», has to confront the «increasing multimodality of meaning» and recognise the learning potential of «the process of shifting between modes and re-representing the same thing from one mode to another» (pp. 178-179). In this sense, Yore and Treagust (2006) and Tang, Delgado and Moje (2014) claim that a deeper insight into the role of this representational diversity in developing Science knowledge and literacy is as crucial as orientating teacher education and professional practices. Therefore, the learning of the language and literacy practices can become an essential part of Science education, as Seah and Silver (2018) advocate.

These practices may be favoured within a CLIL environment, which is attentive to working on how to use language and how to learn to use it. Meyer, Coyle, Halbach, Schuck and Ting (2015) convey that the development of multimodality for Science knowledge and communication, in more than one language, may be fostered by CLIL, if gradually and iteratively implemented. At the same time, a multimodal approach can have positive implications in scaffolding the CLIL Science classroom (Fernández-Fontecha, O'Halloran, Wignell, & Tan, 2020). As emerged from empirical works (Piacentini et al., 2019; Blanchard et al., 2014; Canet Pladvall & Evinitskaya, 2011; Fernández-Fontecha et al., 2020; Meyer et al., 2015; Moore et al., 2018), CLIL can challenge Science teachers to "embrace" also the Science languages, modes or representations and to enrich them, with other verbal strategies and practical interventions (see Piacentini et al., 2017). Multiple studies state that more awareness is actually required of Science teachers to understand the language demands in learning scientific topics, that students whose L1 is not the schooling language have (Buxton & Lee, 2014; Cabello et al., 2019; Lyon, Bunch, & Shaw, 2012; Seah & Silver, 2018), as much as in general (Bezemer & Kress, 2020; Halliday & Martin, 1993; Lemke, 2003; Wellington & Osborne, 2001).

In the European framework CLIL teachers are usually content teachers "confronting" the additional language (Oattes et al., 2018) and whose language teacher role is different from the one of FL teachers, who can not support learners with (Science) genres (doing, explaining, arguing, etc.) and registers (Nikula, 2015) nor develop the language from the point of view of a non-linguistic subject (Gajo, 2007). On the other hand, Valdés-Sánchez and Espinet's work (2020) shows that, within CLIL programmes where the FL teacher and the Science one are co-teaching the specific discipline, a Science teacher sub-identity is promoted in the former teacher («fostering scientific literacy to promote responsible lives; working with a limited number of foundational concepts; relating these concepts to everyday experiences; building new scientific understanding based on children's ideas; working through inquiry», p. 2433). This constitutes a further opportunity for learning Science, in the sense implied by Salehjee and Watts (2020).

DOI: https://doi.org/10.6092/issn.1970-2221/12646

3.5. CLIL Science studies and gaps in (CLIL) Science education research

More endeavour is necessary to understand how the construction of scientific knowledge develops through language and other modes of communication (Scott et al., 2006). With regard to CLIL learning environments in which an additional language (frequently, English) has to be learnt besides the L1, research has focused on advantages for the students' FL skills and attitudes towards language learning, having shifted only recently to concerns related to content knowledge acquisition (Meyerhöffer & Dreesmann, 2019). Recent studies show that Science content scores for primary CLIL students are lower in comparison to non-CLIL learners of same age (Fernández-Sanjurjo et al., 2019; Hughes & Madrid, 2020), but performance improves by the time students reach secondary education. From Hughes and Madrid's perspective (2020), this situation can be «tolerated as a natural part of the development of future plurilingual citizens» (p. 57). Fernández-Sanjurjo et al. (2019) also warn that additional studies in a diversity of contexts are required to achieve a comprehensive vision of CLIL.

A greater collaboration between applied linguists and researchers in subject-specific education is sought (Nikula, Dalton-Puffer, & Llinares, 2013), and «a more integrated approach to further research» (Williams & Tang, 2020, p. 20). Nevertheless, as made clear in section 2. and from journal sources (see References), most studies in CLIL Science originate from the Language research field. Moreover, in a recent review study on "teaching strategies for scientific practices" (Halawa, Hsu, Zhang, Kuo, & Wu, 2020), articles from five target journals connected with Science Education and having "ESL [English as a Second Language] students as participants" were excluded. On the other hand, within the 40 studies included in Williams and Tang's review (2020) on "non-linguistic modes of meaning for language learners in science", essentially all of the reviewed articles encompassed "language learners" in Science classrooms where the majority of students are native speakers of the language of schooling (most of the time, English). In CLIL classrooms all students have to learn a different language from their home one, being learners of the target language.

It is also worth pointing out that, to the author's knowledge, studies specifically directed at CLIL Science education have still not paid attention to the "flux" – to be interpreted as relation rather than comparing – between the presence of English in CLIL Science conditions and Science teacher practices when the language of instruction is, typically, the mother tongue (non-CLIL conditions)[xi]. For these reasons, the understanding of the role of Language(s) in Science teaching and learning through the examination of both non-CLIL and CLIL practices is pivotal (Piacentini et al., 2019), and their incorporation into a broader language focus (Piacentini et al., 2017) may contribute to allowing teachers to become language-aware in the planning, implementation and assessment of Science classes.

Pérez Costa and Pavón Vázquez (2019) remark that teachers should reflect on the fact that the language comprises both the language of the "academic content", which belongs to the subject area, and the "conversational use", that is, how meaning is constructed with students, using either L1 or FL. Reflecting on the language demands of (CLIL and non-CLIL) Science learning and on related teaching practices might mean enhancing teacher education in order to, as recommended by Pérez Cañado (2016), «equip CLIL teachers to bear the challenge of that change [a CLIL-mediated educational innovation]» (p. 217). Ultimately, it might also mean moving CLIL research forward, from investigating a context to advance proficiency in English towards one

DOI: https://doi.org/10.6092/issn.1970-2221/12646

also fueling the largest domain of Science education research internationally, that is, the teaching and learning of Science (see Duit, 2007).

3.6. CLIL and Science education

In order to summarise and give a meaning to the review presented above, we illustrate the content of the state of the art through the diagram of Fig. 1, proposing an innovation for the CLIL acronym, restructuring it as Language, Integrated Learning and Content (L.IL.C.). Our figure (and text) attempts to track a diachronic evolution (from the emergence of CLIL as one European solution for competence in FL to more recent studies highlighting its effect on the specific subject learning) but also synchronic (studies from different times but feeding into the same division in the figure), with the diagram covering but simplifying previous sections. This state of the art brings a new perspective on CLIL as an educational approach that might support the development of a Science education with a focus on Language, and provides opportunities for future research.

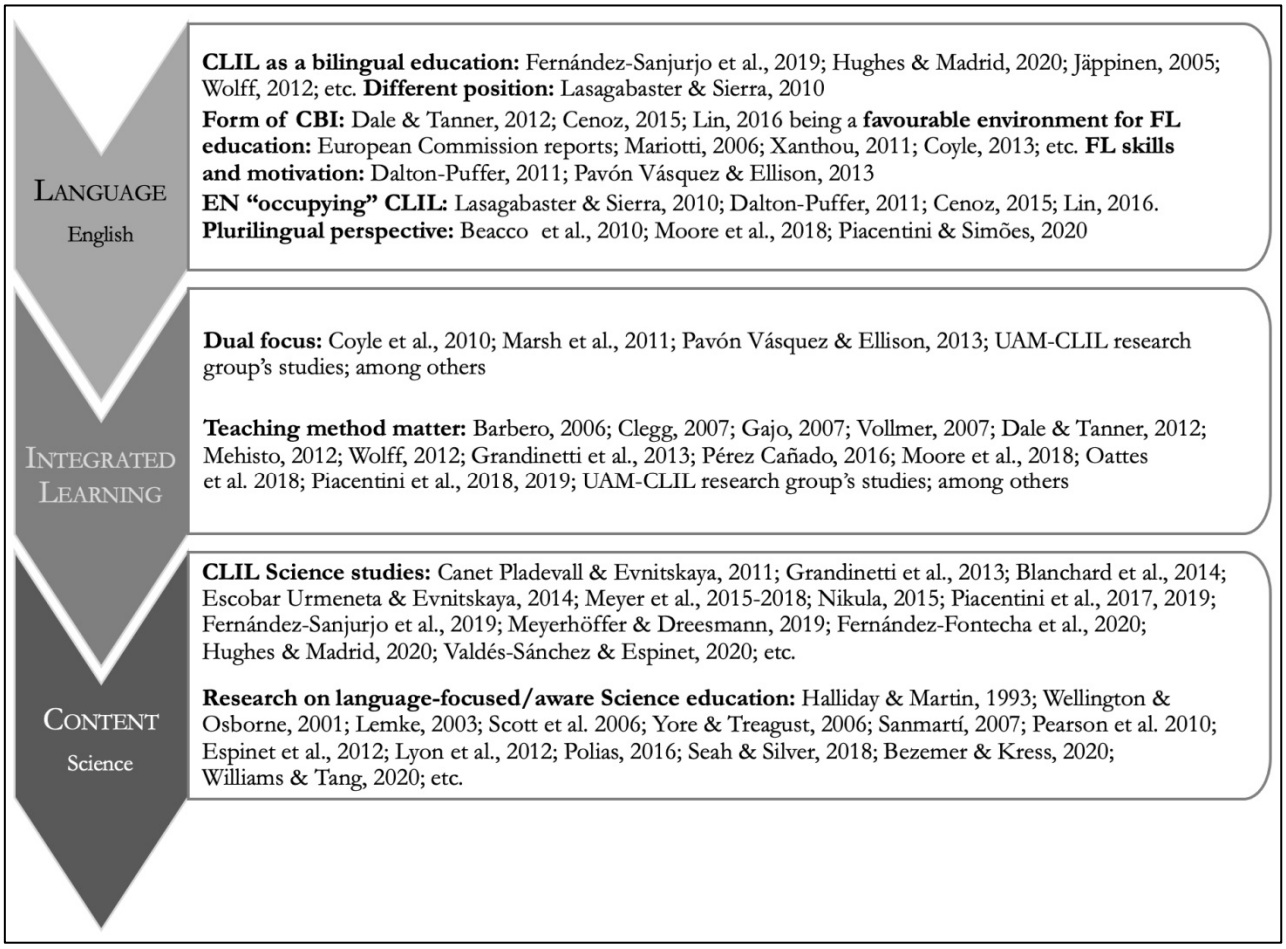

Figure 1: Language, Integrated Learning and Content (revisited CLIL acronym): pertinent aspects and related research

DOI: https://doi.org/10.6092/issn.1970-2221/12646

4. Conclusion

It would be a mistake to deem CLIL mainly to be a domain of language education and linguistics research, owing to the presence of a FL. By drawing a state of the art review on this cross-curricular methodology, starting from CLIL studies and leading to Science education research, the present article shows that positive implications for both the FL (English, in most cases) and the teaching/learning of Science exist. CLIL has emerged, in the European context, as a solution for advancing foreign language learning at school. However, some studies bring evidence that teachers engaged in these educational conditions might change and improve their teaching (strategies, resources, attitudes) through increased awareness of the demands of the language itself and the Language(s) of Science (verbal in the native and additional language as well as other representation modalities) for students. This seems to happen because of the FL/L2 integration within the planning and implementation of Science classes. Therefore, CLIL Science classes may offer a language-aware environment beneficial for Science education, in addition to being an authentic opportunity for speaking and learning English (or other FL).

In terms of CLIL, our review is limited to the European reality and to studies within this setting. Further research is needed to identify and characterise other contexts where CLIL Science has been increasingly implemented (Latin America, Asian countries, etc.). It will also be fundamental to understand what scaffolding techniques are deployed by Science teachers in relation to the languages they elicit and develop in classroom, across different education levels.

Taking the awareness of language into account – from the point of view of non-linguistic subject teachers, like the present work does – can trigger changes in (Science) teacher pedagogy and opens a possibility for researchers to reflect on and orientate teaching methodologies towards a new direction: "SCIL" (Science Constructed through the Integration of its Languages), which can contribute to the development of scientific literacy through a language-focused Science education.

Acknowledgements

I am grateful to reviewers of this manuscript in all its forms, whose perspective improved the paper both conceptually and structurally, and to the members of my PhD jury. I also thank my colleague/friend Betina Lopes for having "critically" read my article and encouraged its revision, and Vanessa (Martins de Souza) who has been in the same (writing and publishing) boat. And I cannot omit to thank Gareth.

[i] They should be interpreted in a broader meaning than just specialised languages of scientific fields (Biology, Physics, etc.), rather, they are opportunities for representing and communicating Science concepts and processes, through different languages: verbal (spoken and written), visual (graphs, tables, diagrams, drawings), mathematical (formulas, equations, calculations), kinaesthetic (action and observation to make sense within experimental procedures and operations), etc. (cf. Lemke). Studies of Science education research are devoted to both "multiple representations" – representing to students the same concept through different forms – and "multimodality" – simultaneous use of different modalities within and across representations – (cf. Tang et al., 2014); based on Lemke, multiple modes or languages or semiotic systems are equally associated with the adjectives multimedia or multimodal. The "reconfigured" multimodality by Cope and Kalantzis (2009) entails the separation be-

DOI: https://doi.org/10.6092/issn.1970-2221/12646

tween written and oral language and a wider range of modes (pp. 178-179): visual (different from Lemke's one), audio, gestural, emotional, spatial and including a tactile representation (which would also encapsulate Lemke's kinaesthetic one).

[ii] Language additional to the mainstream language of instruction, being either a foreign language or a second one, chosen as the target CLIL language.

[iii] This directory has been chosen for being "the largest abstract and citation database of peer-reviewed literature" and for having a broad coverage in terms of time and content (see www.scopus.com).

[iv] In French, EMILE, *Enseignement d'une Matière par l'Intégration d'une Langue Etrangère*; in Spanish, AICLE, *Aprendizaje Integrado de Contenidos y Lenguas Extranjeras*.

[v] A broad category encompassing different programme models and curricular approaches, such as immersion, sheltered instruction, LAC and the CLIL itself, through which teachers and researchers have a common commitment to exploring and researching ways of helping the learning of language and content at the same time.

[vi] Key lexis and phrases, as well as grammatical structures and discourse functions associated with the theme (to define, to explain, to report, etc.) and needed to know how to use thematic words.

[vii] This language does not vary from one subject to another one; students have to learn it for operating effectively in a CLIL unit (to present a project, to work in groups, etc.).

[viii] Emerging when the learners neither have it nor possess the resources to produce it, it is important for recycling and extending the student's repertoire.

[ix] At a verbal level, paraphrasing, reinforcing definitions, waiting for the answer, using corrective feedback techniques, developing questions gradually, use of rhymes, etc.; visually, the use of diagrams, word wall, videos, concept maps, etc.; modulating gazes, gestures, etc.; and other teacher practices as those already mentioned in the main text (see E. and F. sections of the tool in Piacentini et al., 2017). Recently, "visual thinking" has been proposed as a "multimodal methodology" for mediating CLIL (Fernández-Fontecha et al., 2020).

[x] Processes involved are conceptualisation through mediation (paraphrasing, by means of useful descriptions; subject paradigm) and clarification through remediation (translation, to get to the right word; language paradigm), and leading to the development of a new communicative competence which includes authentificating the language for mediating and remediating problems, of conceptual density and linguistic opacity, respectively (Gajo, 2007, pp.568-569).
knowledge and its density

[xi] These aspects have been investigated in the author's PhD dissertation (Piacentini, 2020), within one Portuguese CLIL Science project at lower secondary school.

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DOI: https://doi.org/10.6092/issn.1970-2221/12646